TÍTULO DEL TRABAJO

"Dynamics of *Typha latifolia* population in a free water surface flow constructed wetland in Estonia"

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FIGURAS Y TABLAS

4 figuras y 1 tabla

"Dynamics of *Typha latifolia* population in a free water surface flow constructed wetland in Estonia"

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SUMMARY
The aim of this paper is to evaluate common cattail (*Typha latifolia*) biomass production and annual assimilation of nutrients (N, P) and heavy metals (Cd, Zn, Cu, Pb) in phytomass in order to find information to work out management schemes for increasing cattail biomass production that improve the wastewater treatment capability in a free water surface flow (FWSF) constructed wetland (CW) in Põltsamaa, Estonia.
The biomass samples (roots/rhizomes, shoots with leaves and spadixes) and litter were collected from 1 x 1m plots in 2002 – 2004. The aboveground biomass varied from 0.32 to 3.02 kg m^{-2}. The roots-rhizomes phytomass values varied from 0.32 to 1.27 kg m^{2}. The average nitrogen (N) content was greatest in spadixes in – 22950 mg N kg^{-1}. The highest average phosphorus (P) content (6470 mg P kg^{-1}) was found in the roots-rhizomes. The highest heavy metals content (3.3 mg Pb kg^{-1}, 73.2 mg Zn kg^{-1}, 15.9 mg Cu kg^{-1}, 0.01 mg Cd kg^{-1}) was observed in root and rhizome samples.
KEY WORDS: biomass, cattail, heavy metals, nutrients, wastewater.

"Dinámica de poblaciones de *Typha latifolia* en un humedal artificial de flujo superficial en Estonia"

RESUMEN: El objetivo principal de esta investigación es evaluar la producción de biomasa, la producción anual de nutrientes (N, P) y la producción de metales pesados (Cd, Zn, Cu, Pb) en fitomasa de la espadaña (*Typha latifolia*), de manera que se obtenga la información necesaria para obtener esquemas de gestión con el objetivo de mejorar la capacidad de depuración de aguas residuales mediante un incremento de la producción de biomasa de espadaña en un humedal artificial de flujo superficial en Pöltsamaa, Estonia.

Las muestras de biomasa (raíces / rizomas, tallos con hojas e inflorescencias) y las muestras de lechos fueron recolectadas en cuadrículas de 1m. x 1m. durante 2002-2004. La biomasa variaba de 0.32 a 3.02 Kg/m^2. Los valores de fitomasa de las raíces / rizomas variaban entre 0.32 y 1.27 Kg/m^2. La tasa media de contenido en Nitrógeno fue mucho mayor en las spadixes: 22.950 mg N/kg. La mayor tasa media de contenido de fósforo (P) (6470 mg P/kg) se encontró en los rizomas de las raíces. El mayor contenido de metales pesados (3.3 mg Pb kg^{-1}, 73.2 mg Zn kg^{-1}, 15.9 mg Cu kg^{-1}, 0.01 mg Cd kg^{-1}) fue observada en las muestras de raíces y rizomas.
PALABRAS CLAVE: biomasa, espadaña, metales pesados, nutrientes, agua contaminada.

1. INTRODUCTION

The production of emergent macrophytes used in constructed wetland can vary from 0.7 to 11 kg m^{-2}, uptake of nitrogen from 12.5 to 585 g m^{-2} and uptake of phosphorus from 1.8 to 112.5 g m^{-2} (Kadlec and Knight, 1996). The tolerance of some macrophytes to high concentrations of lead (Pb), zinc (Zn), copper (Cu) and nickel (Ni) has been demonstrated (Taylor and Crowder, 1984).

The plants do not play a mayor role in purification processes, however the existence in wetland system for wastewater treatment is important. The changes in vegetation may affect purification efficiency (Kadlec and Knight, 1996; Brix, 1997; Vymazal, 2002).

Some emergent wetland macrophyte populations, which firstly were established by planting in soil in the bottom of a wetland, are capable to form floating mat. Their individual plants are not capable of such existence. This change may take only two years and most of the plants become rooted in a floating mat of decaying litter on the wetland surface (Anonymous, 2000).
The aim of this paper is to evaluate common cattail (*Typha latifolia*) biomass production and annual assimilation of nutrients (N, P) and heavy metals (Cd, Zn, Cu, Pb) in phytomass in order to find information to work out management schemes for increasing cattail biomass production that improve the wastewater treatment capability in a free water surface flow (FWSF) constructed wetland (CW) in Põltsamaa in Estonia.

2. MATERIAL AND METHODS

Biomass production and nutrient and heavy metal assimilation by cattail were studied in the Põltsamaa FWSF CW. The system is a cascade of 4 serpentine ponds (Fig. 1) located in the flood plain of the Põltsamaa River. It is designed for the secondary treatment of wastewater from the conventional treatment plant consisting of mechanical filters, sedimentation tanks and aeration tanks. It treats wastewater from the town of Põltsamaa with about 5000 inhabitants and from food processing factory. The system was constructed in 1997. The ponds' areas are: first – 0.15 ha, second – 0.17 ha, third – 0.65 ha and fourth – 0.24 ha (total area is 1.21 ha). The average water depth in the first pond is 1.0 m and in other three 0.5 m (Mander et al, 2001).

Cattail was planted in the bottom of the second, third and fourth pond in summer 1998, within some years rhizomes-roots became woven together and accumulate decaying leaf litter to form a floating mats on the wetland surface. Cattail floating mats have not colonised all the surface of ponds.

sampling plots (1-15).

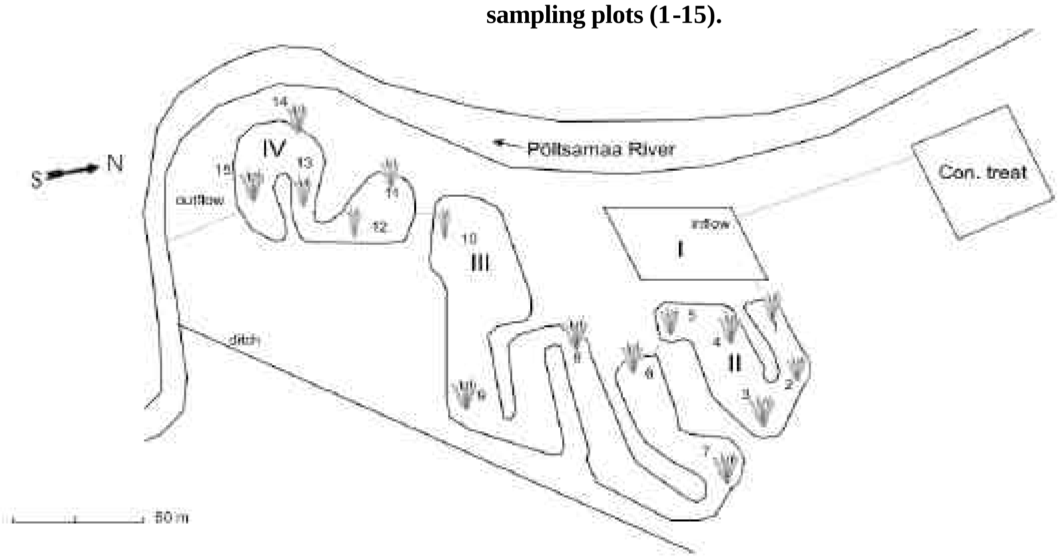

Figure 1. The Põltsamaa free water surface flow constructed wetland. There are shown location of

The cattail phytomass measurements were performed after maximal growth of macrophytes, at the end of August and the beginning of September in 2002, 2003 and 2004. Cattail was divided into four fractions: roots-rhizomes, shoots with leaves, spadixes and litter. The samples were collected from 1m^2 plots. All samples were dried to a constant weight at 70?C. The dry weight (DW) of cattail fractions was measured on 15 plots, the nutrient and heavy metal content of each fraction was analysed from 9 and 6 samples, respectively. Nutrient content analyses were made by two first year fraction samples and heavy metal content analyses were made only by first year fraction samples.

The statistical analysis was carried out using STATISTICA 6.0 (StatSoft Inc.) program. The normality of the variables was verified using the Lilliefors' and Shapiro-Wilk W tests. Heavy metals content variables were not normally distributed. Biomass production and nutrient content variables were normally distributed. The 95% confidence intervals were used to compare wetland means. Level of significance a= 0.05 was accepted in all cases.

3. RESULTS

The aboveground biomass varied from 0.32 to 3.02 kg DW m^{-2}. The roots-rhizomes phytomass values varied from 0.32 to 1.27 kg DW m^{-2}. Results from 2003 showed somewhat lower values (Fig. 2). The average biomass of shoots was increasing almost two times from 0.84 to 1.58 kg DW m^{-2} and the biomass of spadixes was decreasing from 0.1 to 0.06 kg DW m^{-2}. There was significantly more litter (0.48 kg DW m^{-2}) in 2002 than in 2003 and 2004 (0.1 and 0.13 kg DW m^{-2}, respectively).

The average nitrogen and phosphorus content in litter was significantly lower than in the other fractions in 2002 (Fig. 3). There was significantly higher content of phosphorus in roots-rhizomes in 2003, but nitrogen content did not vary significantly.
The average nitrogen (N) content was greatest in spadixes in 2002 – 22950 mg N kg^{-1}. The highest average phosphorus (P) content (6470 mg P kg^{-1}) was found in the roots-rhizomes in 2003.

A positive correlation between N and P concentrations in cattail fractions showed that these nutrients were stored in reserve organs after fruiting stage.

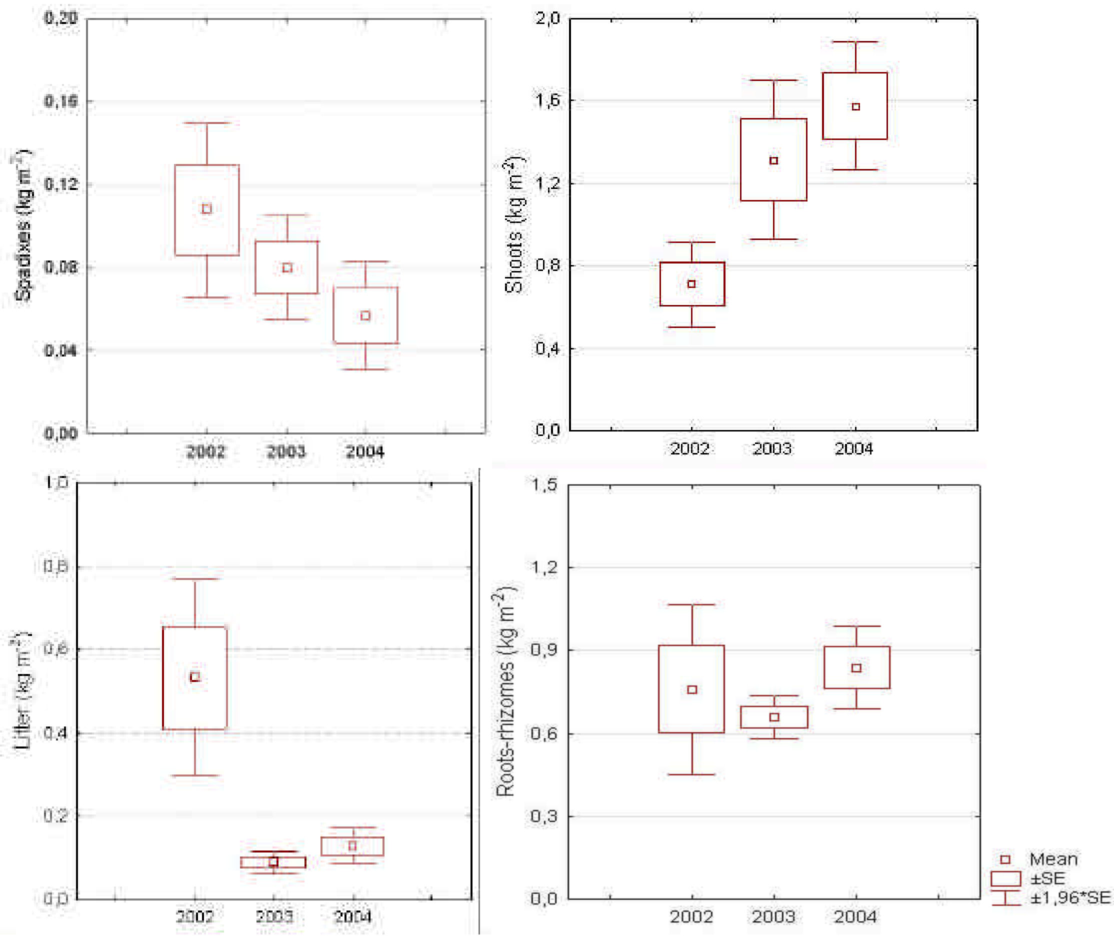

Figure 2. Cattail phytomasses in the Põltsamaa FWSF CW in 2002, 2003 and 2004.

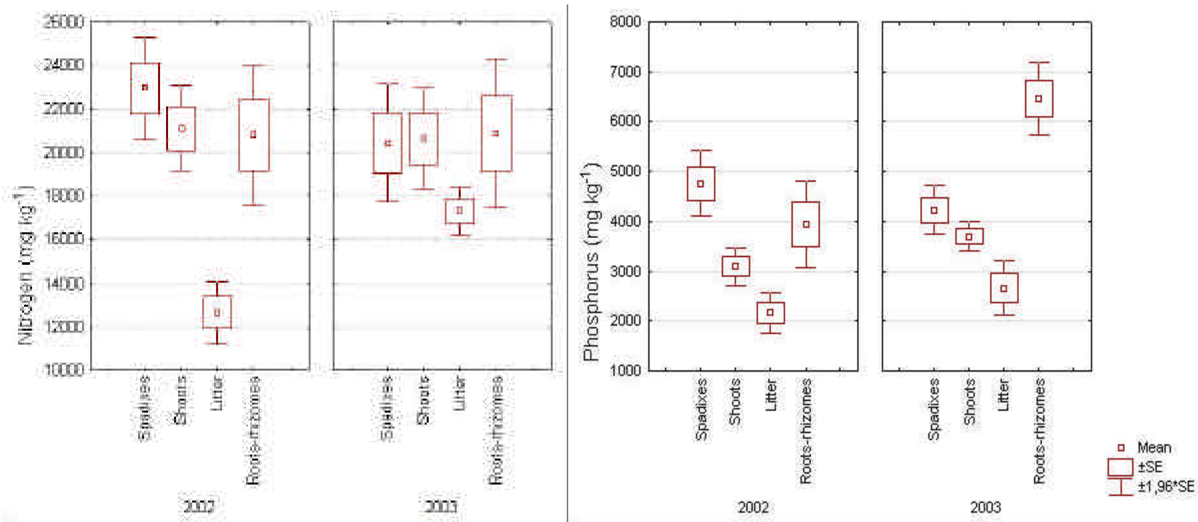

Figure 3. Nitrogen and phosphorus content (mg kg^{-1}) in cattail fractions in the Põltsamaa FWSF CW in 2002 and 2003.

Values of Cd, Cu, Pb and Zn contcentrations in fractions of *T. latifolia* are shown in Figure 4. The Cd concentrations in all samples (shoots, spadixes, litter) varied from <0.01 mg kg^{-1} to <0.02 mg kg^{-1}. The average Pb content was the same in almost all shoot samples, namely <0.1 mg kg^{-1}. The average content of Cu in shoots was 3.6 mg kg^{-1}. The average content of Zn in shoots was 15.4 mg kg^{-1}.

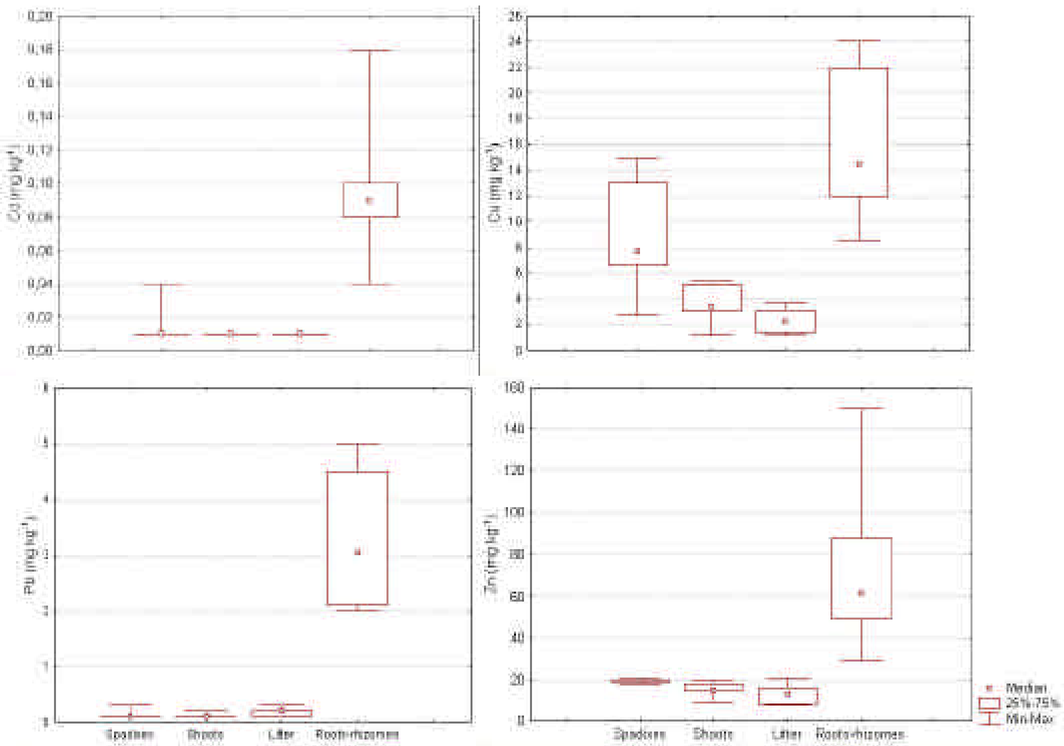

Figure 4. Cd, Cu, Pb and Zn content (mg kg^{-1}) in cattail fractions in Põltsamaa FWSF CW.

The lowest heavy metals contents were found in litter. The average concentration of Zn, Cu and Pb was 13.3, 2.3 and 0.2 mg kg^{-1}, respectively. The average Zn content in spadixes was 19.6 mg kg^{-1}, whereas Pb and Cu concentrations were 2.0 and 9.0 mg kg^{-1}, respectively. We measured 3.3 mg Pb kg^{-1}, 73.2 mg Zn kg^{-1}, 15.9 mg Cu kg^{-1} and >0.01 mg Cd kg^{-1} in roots and rhizomes.

There was found significant positive correlation between the fractions of aboveground fractions, but the belowground phytomass values did not correlate with the aboveground phytomass.

The highest accumulation of nutrients occurred in roots-rhizomes and shoots showing significantly higher values than in litter and spadixes (Table 1). The uptake capacity of total cattail biomass in Põltsamaa was in the range 41.5 to 46.9 g N m^{-2} and 5.7 to 6.0 g P m^{-2}.

Table 1. Retention rates of N, P (both in g m^{-2}), Cd, Zn, Cu, and Pb (all in mg m^{-2}) in cattail compartments in the Põltsamaa FWSF CW in 2002 and 2003.

Fraction	N	P	N	P	Cd	Zn	Cu	Pb
	g m^{-2}				mg m^{-2}			
	2002		2003		all in 2002			
Roots/rhizomes	15.0	2.9	14.8	4.6	0.08	12.1	2.5	55.6
Litter	6.5	1.2	1.5	0.25	0.005	1.22	0.11	7.1
Shoots	17.7	2.6	28.9	5.35	0.07	2.54	0.07	10.9
Spadixes	2.4	0.5	1.7	0.4	0.001	0.24	0.24	2.4

The accumulation of heavy metals in roots-rhizomes were significantly higher than in other fractions (Table 1).

4. DISCUSSION

The average total biomass of *T. latifolia* in Põltsamma FWSF CW varied from 2.15 to 2.6 kg DW m^{-2} in three years study. The average aboveground and belowground phytomass results were in agreement with results by Romero et al (1999) and Wild et al (2002). Nutrients contents in cattail tissues were similar to that estimated by Kadlec and Knight (1996) and Ennabili et al (1998). Heavy metal contents in cattail fraction in Põltsamaa were not significantly different from results of two other study sites in Estonia (Maddison et al, 2005).
The elements assimilation in plants depends on the production, therefore variations in biomasses affected also variations in nutrient assimilation.

The nutrient uptake capacity of cattail in Põltsamaa FWSF CW was considerably high, and thus amounts can be removed if the biomass is harvested. Whereas heavy metals concentrations in cattail were generally low and harvesting of total aboveground biomass has only a minor influence on heavy metals removal from free-water surface constructed wetlands.

The N and P content in plant fractions demonstrated that these nutrients were stored in reserve organs after fruiting stage. A positive correlation between N and P concentrations in cattail fractions was found. The highest content of heavy metals in the roots and rhizomes of cattail showed a significant higher accumulation capacity of belowground phytomass than aboveground phytomass, but also low mobility within plant fractions.

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